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CONTROL OF *DERMACENTOR VARIABILIS*.[1] 1. LARVAL AND ADULT SUSCEPTIBILITY TO SELECTED INSECTICIDES

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Abstract.—The relative susceptibility of the American dog tick, *Dermacentor variabilis,* to selected insecticides was determined in the laboratory by larval exposure to insecticide-treated surfaces and by adult exposure to topically applied insecticides. Subsequent field experiments were conducted with caged ticks to determine the potential of these insecticides for use in area control of *D. variabilis* adults. Results from both field and laboratory experiments indicate that emulsifiable formulations of naled and chlorpyrifos were highly effective acaricides, more toxic to larval and adult ticks than acephate, propoxur, pyrethrins and ronnel, as demonstrated by LC_{50} and LC_{90} values.

Due to the prevalence of the American dog tick, *Dermacentor variabilis* (Say), on Long Island, New York (Anastos 1947; Collins et al. 1949; Good 1973), and the recent increase of Rocky Mountain Spotted Fever (RMSF) cases on Long Island (Benach et al. 1977), we wished to determine the relative susceptibility of larval and adult *D. variabilis* to certain insecticides under laboratory conditions and to determine the efficacy of field applications of these insecticides for the control of *D. variabilis* (White et al. 1980a, b).

Local environmental legislation and court actions precluded the use of some insecticides and acaricides already labeled for area tick control. Thus, our aim in studying the susceptibility of *D. variabilis* adults and larvae was to attempt to increase the choice of insecticides available for area control. Field applications of nonlabeled chemicals for *D. variabilis* control were made possible by experimental use permits from the New York State Department of Environmental Conservation, as per Part 172 of the Federal Insecticide, Fungicide and Rodenticide Act of 1972.

This is the first of 3 reports aimed at the control of questing *D. variabilis* in areas where attachment to humans and domestic animals is most likely to occur. In this paper, we report the results of laboratory and field efficacy trials of 6 insecticides against *D. variabilis*.

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[1] Acari: Ixodidae.

Materials and Methods

Larval bioassays.—Larvae utilized for bioassay experiments were reared in the laboratory from eggs obtained from field-collected engorged *D. variabilis* females. Larvae were kept in moist cotton-stoppered plastic tubes within desiccator jars containing a saturated solution of NH_4Cl. Adult ticks were collected for bioassay experiments by dragging a piece of white flannel cloth (1 m^2) along vegetation adjacent to roadsides and paths in various areas of Long Island. Captured ticks were placed in moist cotton-stoppered tubes, brought to the laboratory, and maintained in the same manner as larvae.

Larval exposure to each chemical dilution was accomplished by slightly modifying techniques reported by Hansens (1956). Filter paper (12.9 cm^2) was used to line the insides of 3.7 ml screw-cap vials. A uniform amount (0.15 ml) of each insecticide dilution was added directly to the filter paper in each vial. Control vials received 0.15 ml of distilled water. Ten 8- to 10-week-old unfed larvae were placed with needle-point forceps directly on the moist filter paper in each of the 12 vials. Two replicates of 5 chemical concentrations and of controls represented a test series for the laboratory bioassays.

The treated surface experiments involved emulsifiable concentrate formulations of chlorphyrifos (*O,O*-diethyl *O*-(3,5,6-trichloro-2-pyridl) phosphorothioate) from 36 mg to 1.5 mg a.i./vial and ronnel (*O,O*-dimethyl *O*-2,4,5-trichlorophenyl phosphorothioate) from 108 mg to 10.8 μg a.i./vial, courtesy of Dow Chemical Co.; propoxur (*O*-isopropoxyphenyl methylcarbamate) from 20 mg to 20 ng a.i./vial, courtesy Chemagro naled (1,2-dibromo-2,2-dichloroethyl demethyl phosphate) from 840 mg to 840 ng a.i./vial, courtesy Chevron Chemical Co., and pyrethrins with 10% piperonyl butoxide from 1.44 mg to 144 ng a.i./vial, courtesy FMC. In addition to the above, a water soluble powder formulation of acephate (*O,S*-dimethyl acetylphosphoramidothioate), courtesy Chevron Chemical Co., was used in the topical application experiments. The same chemicals were used for field experiments.

Adult bioassays.—Topical applications of various dilutions of the insecticide emulsions proved to be the most efficient method of adult exposure to the chemical in the laboratory. Filter paper (45.1 cm^2) was used to line the inside of 29.6 ml screw-cap vials. The paper in each vial was moistened with 0.5 ml distilled water to provide a source of humidity. One microliter of a chemical dilution was placed on the dorsum of each of 20 ticks (of both sexes) to be treated with that dilution. Individual ticks were restrained by forceps while the chemical was applied and held for 10 s before they were placed into the vials. Ten treated adult ticks were contained in each vial. A regimen of 2 replicates of each of the 5 chemical dilutions and controls represented a test series for the adults. Concentrations of the applied chemicals ranged from 40,000–3,000 ppm for acephate, 3,600–1.5 ppm for chlorpyrifos, 43,500–0.4 ppm for naled, 8,200–0.82 ppm for propoxur, 50,000–500 ppm for pyrethrins with piperonyl butoxide and 7,500–75 ppm for ronnel.

Mortality, defined as the failure of a tick to respond to being breathed upon (Mount et al. 1970), was determined in all vials 24 and 48 h after initial exposure. Since ticks are negatively geotropic, all vials were maintained in a horizontal position at 24°C and a 10:14 h light:dark photoperiod throughout the 48 h test period.

Field tests.—During field experiments, postspray dragging proved to be a variable and inefficient tool (White et al. 1980b) for monitoring insecticide spray efficiency. Therefore, caged ticks were utilized to determine the efficacy of the insecticide applied under field conditions. The plots used for the field trials were open, ca. rectangular fields, ranging in size from 0.4 to 1.6 ha and dominated by 10 to 25 cm high grass vegetation. Ten adult ticks were placed inside each of 12 cylindrical aluminum wire screen cages (ca. 85 cm^3, 4 cm diam × 9 cm long, mesh opening 2.25 mm^2). Cages were supported by stakes 15 cm above the ground (to approximate the position of questing ticks) in rows parallel to the line of travel of the sprayer. A Buffalo Turbine mist blower, model CS, was operated at 14.1 kg/cm^2 (200 psi) with four 0.64-cm (¼″) Tee Jet nozzles (i.e. 2, ¼ TT 6504; 1, ¼ TT 6503; and 1, ¼ TT 6502) and calibrated to deliver 28.2 l/ha (3 gal/acre). The vehicle upon which the blower was mounted had a forward speed of 8 km/h (5 mph), during spray activities. Sprays were delivered downwind when wind speed was no greater than 8 km/h. Immediately after treatment, ticks were transferred to moist cotton-stoppered plastic tubes. Mortality was then determined 24 h after chemical exposure.

Probit analyses (Finney 1964) were conducted on laboratory bioassay mortality data taken at 24 and 48 h.

Results and Discussion

The mean LC_{50} and LC_{90} values, as well as the standard error of the mean, determined at 24 and 48 h after exposure of the tick larvae to the corresponding insecticide, are shown in Table 1. Results of the larval bioassays indicate that, based on LC_{50} and LC_{90} values, naled was the most toxic of the 5 insecticides to *D. variabilis* larvae. According to the 48 h LC_{90} values, naled is from 32× to 554× more toxic to *D. variabilis* than the remaining compounds. The 48 h LC_{90} values of ronnel and synergized pyrethrins indicate that a substantially higher dose was necessary to result in similar morality figures.

Data derived from the topical application experiments on adults are shown

Table 1. Mean LC_{50} and LC_{90} values (ppm) with standard error (SE) of the mean, determined at 24 and 48 h after exposure of *D. variabilis* larvae to surfaces treated with various concentrations of 5 insecticides.

	LC_{50}			LC_{90}		
Chemical	Time	Mean	SE	Time	Mean	SE
Chlorpyrifos	24	2.39	1.15	24	1.99	1.32
	48	0.21	—	48	1.29	—
Naled	24	0.02	0.01	24	0.09	0.05
	48	0.01	0.006	48	0.04	0.01
Propoxur	24	0.64	—	24	3.48	—
	48	0.58	—	48	2.87	—
Pyrethrins	24	2.64	0.16	24	44.44	3.79
	48	0.58	0.41	48	22.14	8.76
Ronnel	24	24.70	11.60	24	60.39	10.09
	48	2.97	1.25	48	13.36	2.93

in Table 2. The mean LC_{50} and LC_{90} values for naled and chlorpyrifos are very similar, indicating that relatively low concentrations of these materials were necessary for effective control. Synergized pyrethrins was the third most active material against topically treated adults followed by ronnel, propoxur and acephate in order of decreasing toxicity. As with the larval experiments, acephate required a very high concentration to produce mortality in *D. variabilis* adults.

Table 2. Mean LC_{50} and LC_{90} values (ppm) with standard error (SE) of the mean, as determined by probit analysis at 24 and 48 h after exposure of *D. variabilis* adults to various concentrations of 6 topically applied insecticides.

	LC_{50}			LC_{90}		
Chemical	Time	Mean	SE	Time	Mean	SE
Acephate	24	4,941.83	356.77	24	28,248.99	3,775.48
	48	2,185.00	1,441.89	48	9,745.27	448.71
Chlorpyrifos	24	7.75	0.50	24	29.84	3.65
	48	6.32	1.16	48	19.08	5.92
Naled	24	8.76	0.64	24	57.50	20.04
	48	7.26	1.04	48	27.30	6.88
Propoxur	24	182.39	15.57	24	673.72	42.52
	48	166.18	14.29	48	574.78	61.47
Pyrethrins	24	26.60	6.28	24	106.24	21.94
	48	25.32	7.56	48	97.13	12.83
Ronnel	24	185.05	35.16	24	519.87	212.73
	48	158.41	26.34	48	418.09	30.38

Table 3. Percentage mean mortality at 24 h of caged adult ticks placed at various distances from the insecticide sprayer and treated with a specific concentration of 1 of 6 insecticides.

Distance (m) from sprayer	Chemical and concentration (actual insecticide)												
	Acephate		Chlorpyrifos		Naled			Propoxur		Pyrethrins		Ronnel	
	6%	3%	0.12%	0.06%	0.36%	0.18%	0.09%	0.22%	0.11%	0.05%	0.01%	0.25%	0.12%
6	100	100	100	100	100	100	100	100	100	100	100	100	100
12	100	75	100	100	100	100	100	100	100	100	80	100	90
18	80	70	100	100	100	100	100	100	90	95	50	100	90
24	75	70	90	100	100	100	100	100	70	100	20	100	65
30	45	55	100	85	100	40	95	100	60	80	10	100	40
Control	10	5	10	5	5	10	5	0	10	0	10	5	5

As illustrated in Table 3, these same emulsifiable chemicals (acephate was formulated as WP) were used to determine relative efficacy for control of caged *D. variabilis* under field conditions. The concentrations were selected arbitrarily based on information already on the label for use under area wide outdoor application and either diluted by ½ or doubled for additional data against the American dog tick. The higher concentrations of each insecticide produced 100% mortality in those caged ticks nearest the point of application in all cases. All concentrations of naled and chlorphyrifos were shown to be very active even when dispersed up to 24 m from the point of application. High concentrations of ronnel and propoxur were effective up to 30 m from the application point, but these concentrations may not be acceptable for area wide outdoor application. Similarly acephate required exceedingly high concentrations to produce mortality. Synergized pyrethrins at 0.05% may be effective for the control of *D. variabilis* but potential applicators should consider the cost/benefit ratios of all materials.

In addition to assessing the utility of the mist blower, the data in Table 3 indicate that both naled and chlorpyrifos are highly active for *D. variabilis*. Choice of material to be used in a control program will depend on availability of the individual materials, registration of the materials in the particular geographic area and chemical cost. These parameters aside, three compounds used in this study, chlorpyrifos, naled, and synergized pyrethrins, can be applied at acceptably low concentrations. The mortality figures produced by propoxur and ronnel show that they require slightly higher concentrations, but if the materials are available and are registered for area use, they may be effective agents for the control of *D. variabilis*. The concentrations required for acephate for effective applications were very high, and as such, does not provide a justification for using acephate against the American dog tick.

Our findings support those of Drummond et al. (1971) who also stated that ronnel was less effective than chlorpyrifos for control of *D. albopictus* Packard. Mount et al. (1970) showed that naled was ca. 10 times as toxic as chlorpyrifos to 1- to 2-month-old *Amblyomma americanum* (L.) nymphs. However, Drummond and Medley (1965) reported that a 0.25% naled formulation was less effective than a 0.75% ronnel in controlling adult *A. americanum* on cattle. Rawlins and Mansingh (1977) indicated that naled exhibited acaricidal effects on 3 Jamaican species of livestock ticks.

The results of laboratory and field insecticide applications have shown that naled and chlorpyrifos are toxic to *D. variabilis* and, when applied under field conditions, will kill them even at concentrations of 0.09% and 0.06%, respectively.

The field caged tick study, as well as the laboratory toxicity study, strongly suggest that naled and chlorpyrifos, when applied by high-pressure, low-volume equipment, can provide control of American dog tick questing populations. Since ticks congregate along paths or roadsides (Smith et al. 1946), an effective and economical control program can be instituted with the objective of controlling populations of *D. variabilis* in these areas. If insecticide applications are made to coincide with peak tick populations (Good 1973; Smith et al. 1946) in areas of endemic RMSF activity, the objective of reducing the probability of human exposure to infected ticks can be realized (White et al. 1980a). Control efforts directed against questing ticks in infected foci could contribute to the decrease of human RMSF cases in given areas.

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